How will we go to Mars?

The Humans to Mars Summit 2015

May 5-7, Washington D.C.

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NASA / Johnson Space Center


Learning from the past
To prepare for the Future

Some Recent Industry & International Assessments

AEROJET ROCKETDYNE

Heavy Lift & Propulsion Technology Systems
Analysis and Trade Study

Final Report
DRD 1372MA-003
3 June 2011

Prepared by

GenCorp Aerojet

Prepared For

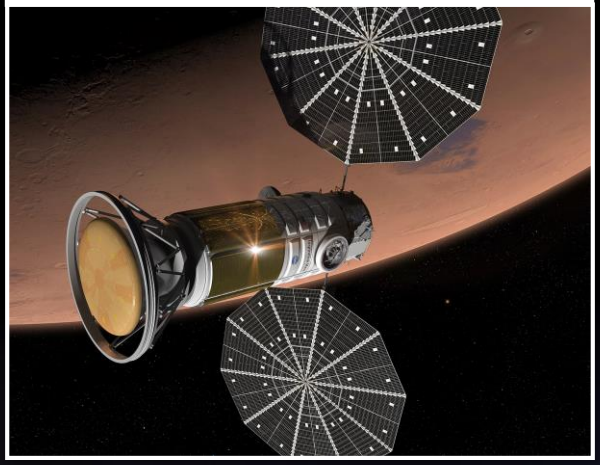
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, AL

AEROJET

Sacramento, CA
Redmond, WA

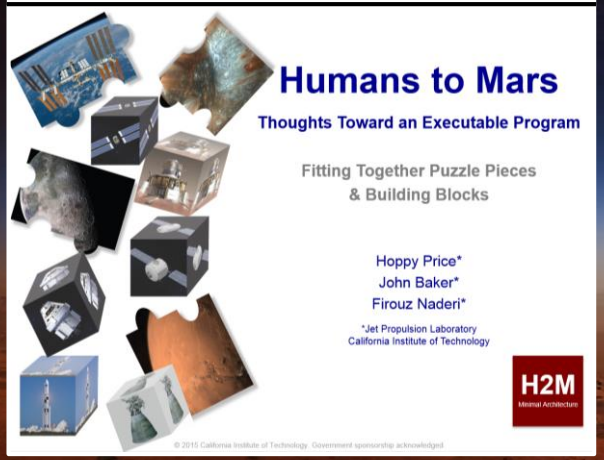
BOEING

Inspiration Mars

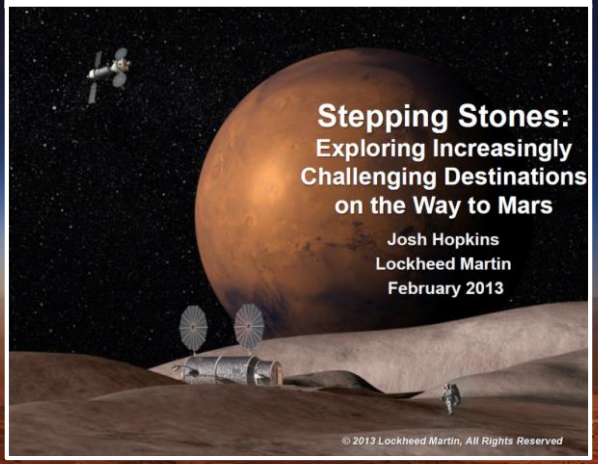


International Coordination

Jet Propulsion Laboratory



LOCKHEED MARTIN



Key Challenges of Human Exploration of Mars

Common Findings from Multiple Studies

1,000 Days

Total time crew is away from Earth

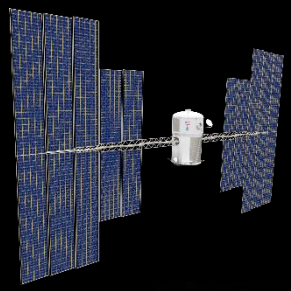
Maximum surface stay for any given mission

500 Days

44 min

Maximum two-way communication time delay

100-200 kWe



Total continuous transportation power

130 t

Heavy-Lift Mass

Multiple

Launches per mission

20-30 t

Ability to land large payloads

12 km/s

Highest Orion Earth entry speed

100 km

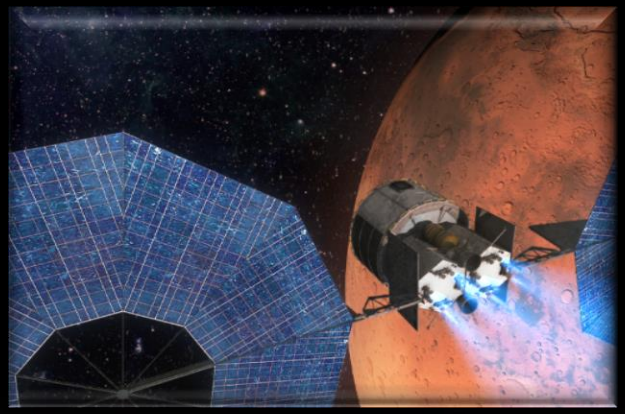
Distance for long-range routine exploration

20 t

Oxygen produced for ascent to orbit

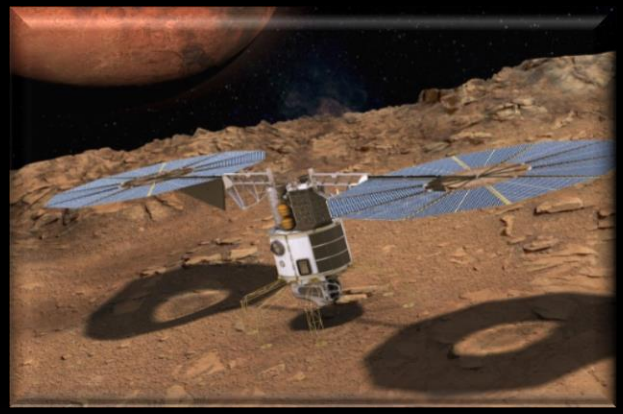
Three New Neighborhoods to Explore

Mars Vicinity Missions Provide the Pull



Mars Orbit

- Round-trip to/from orbit
- Humans in zero-g
- Opportunities:
  - Real-time teleoperation
  - Support Mars sample return



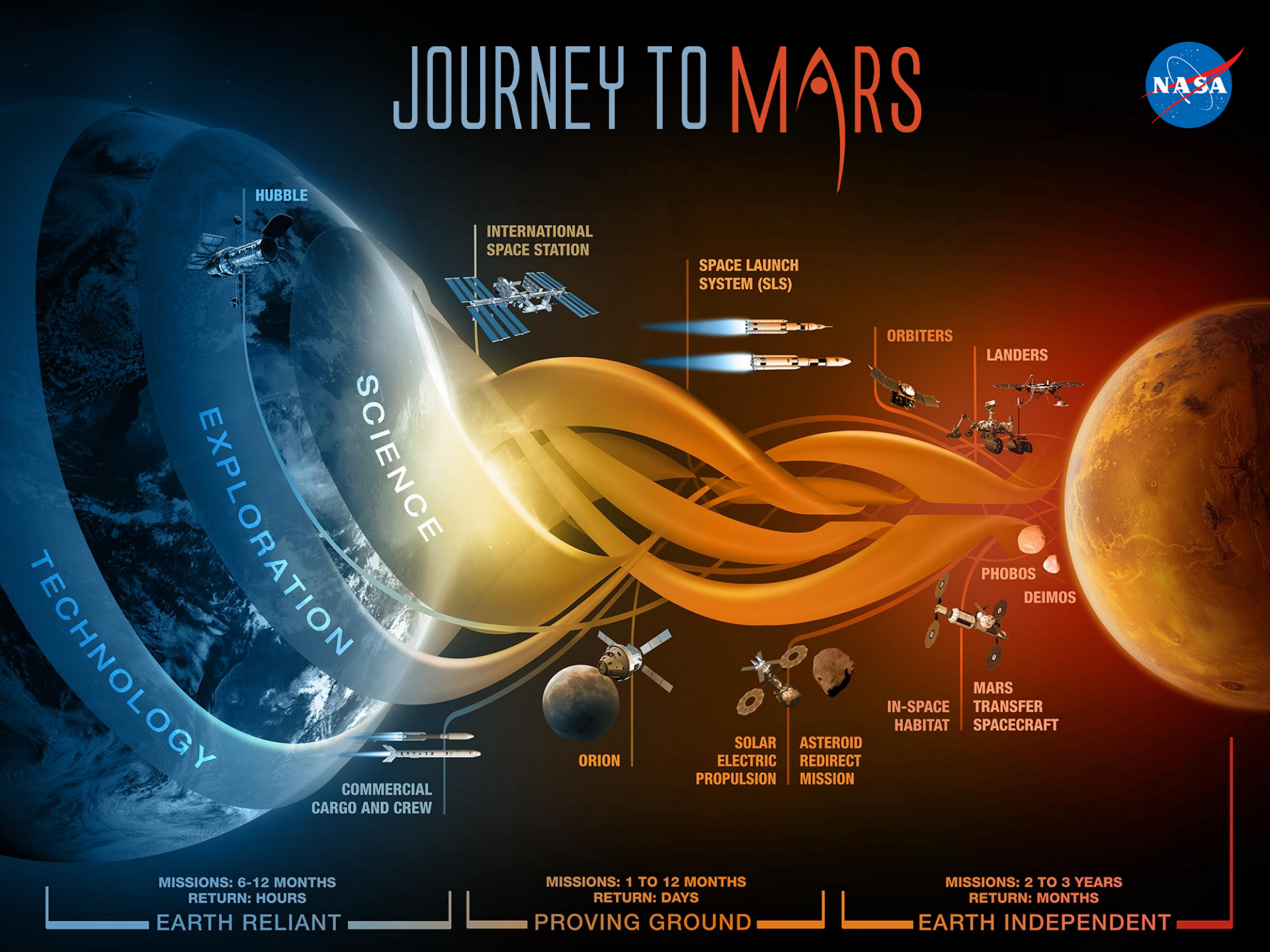
Mars Moons

- Round-trip to/from orbit
- Humans in low-g
- Enhanced radiation protection
- Opportunities:
  - Mars moon exploration
  - Real-time teleoperation
  - Mars & moons sample return

Mars Surface

- First steps on Mars
- Humans in partial-g
- Enhanced radiation protection
- Use resources of Mars
- Initiate pioneering
- Opportunities:
  - Search for signs of life
  - Robust exploration
  - Mars sample return

JOURNEY TO MARS



International Space Station

The First Step in Exploration

Human Health Research

Advanced Life Support

Technology Demonstration

Logistics Management

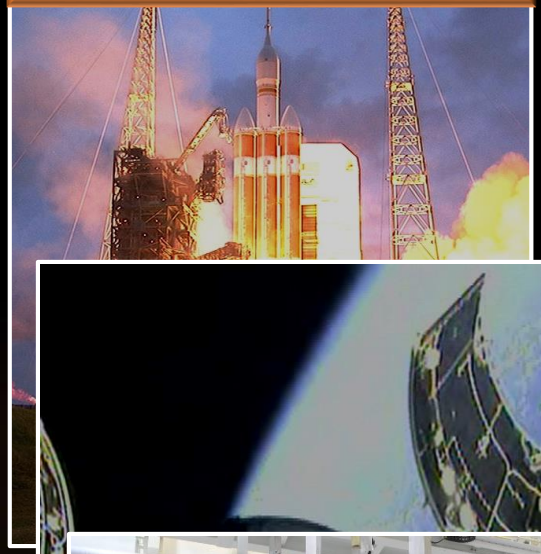
Maintenance & Repair

International Collaboration

SLS, Orion, and Ground Operations

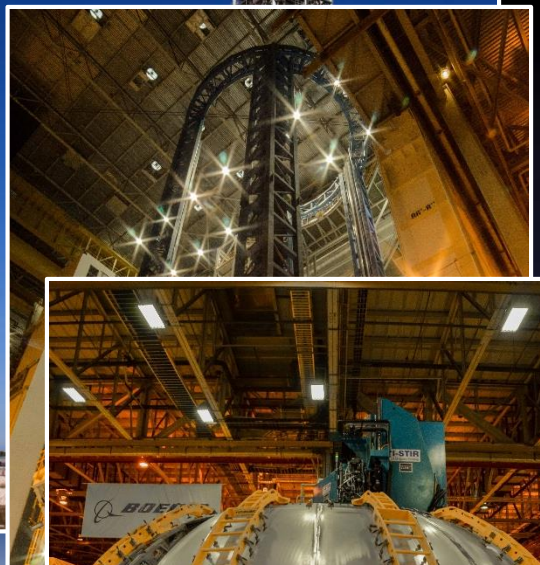
Making Real Progress

Orion



Space Launch System

Ground Operations



Proving Ground Objectives

Enabling Missions to Mars

VALIDATE

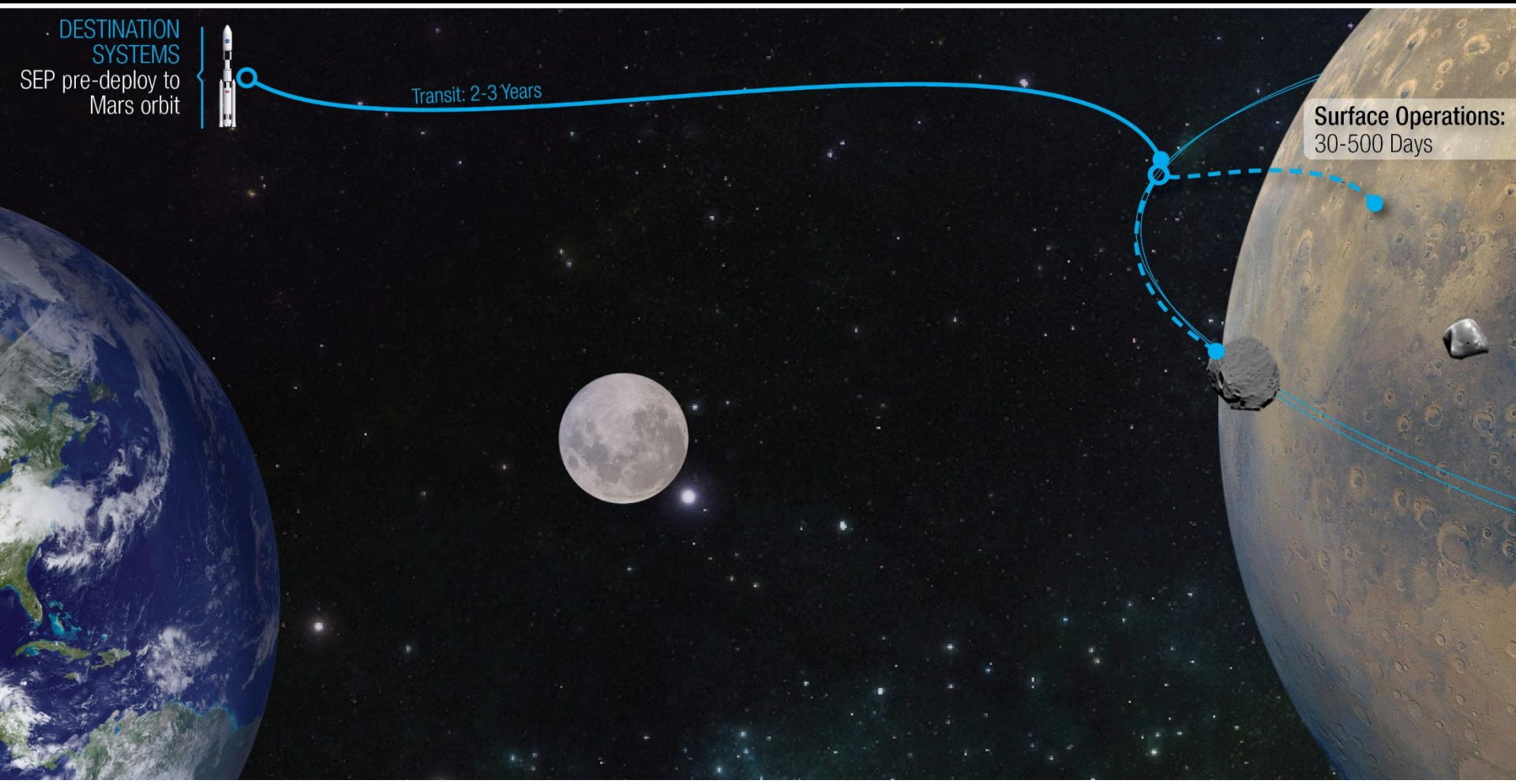
- Cis-lunar space as a staging point for vehicles in route to Mars
- Advanced Solar Electric Propulsion for efficient mass delivery
- Crew health and performance in a deep space environment
- Space Launch System and Orion in deep space
- Long duration, deep space habitation systems
- Operations with reduced logistics capability
- Structures and mechanisms
- In-Situ Resource Utilization

CONDUCT

- EVAs in deep space with sample handling
- Integrated human and robotic mission operations
- Capability pathfinder missions to reduce strategic knowledge gaps

Split Mission Concept

Pre-Deploy Cargo First

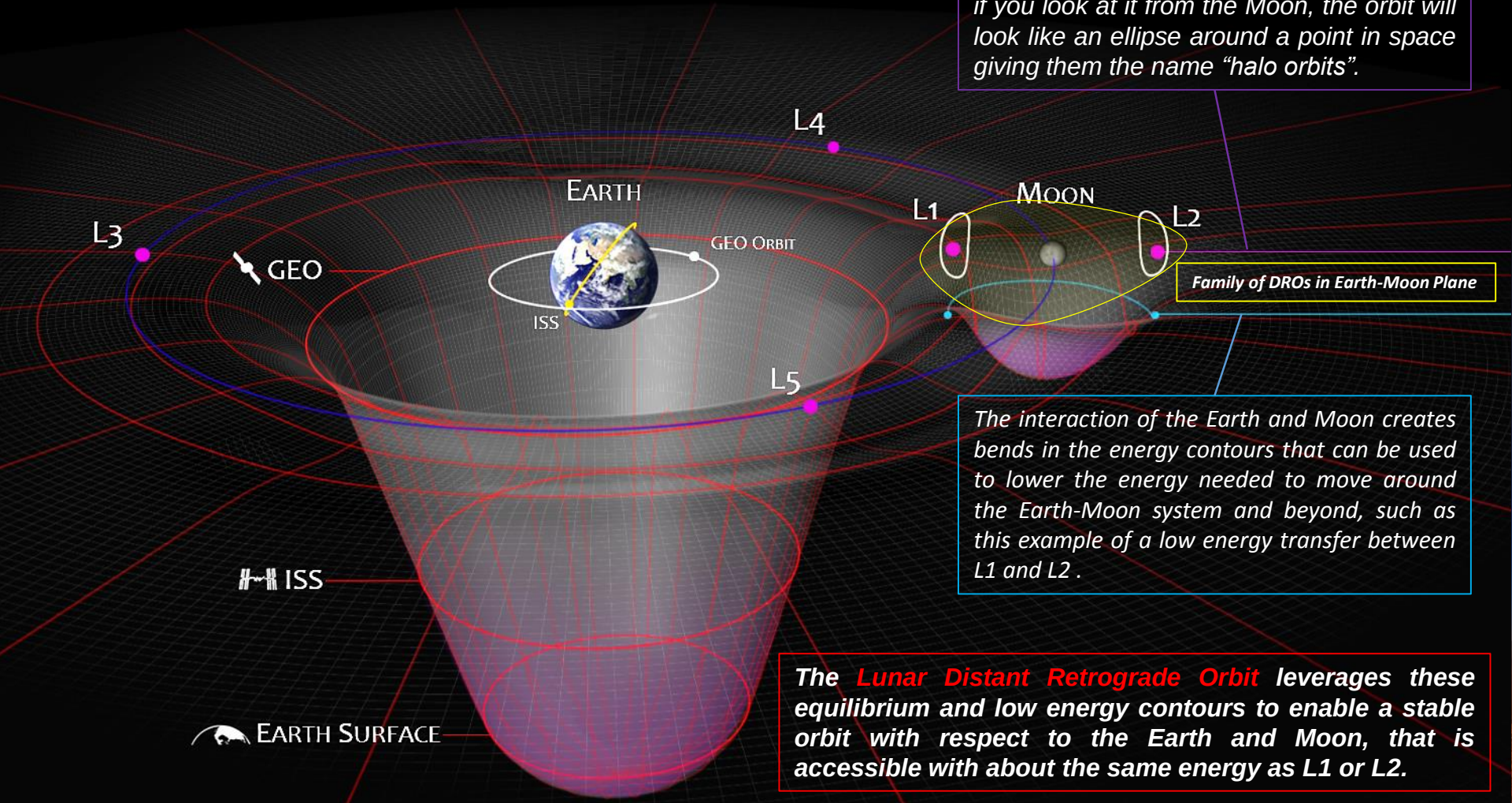


Cis-Lunar Space

How the Earth and the Moon Interact

The contours on the plot depict energy states in the Earth-Moon System and the relative difficulty of moving from one place to another.

A spacecraft at L2 is actually orbiting Earth at a distance just past the Moon, however if you look at it from the Moon, the orbit will look like an ellipse around a point in space giving them the name "halo orbits".

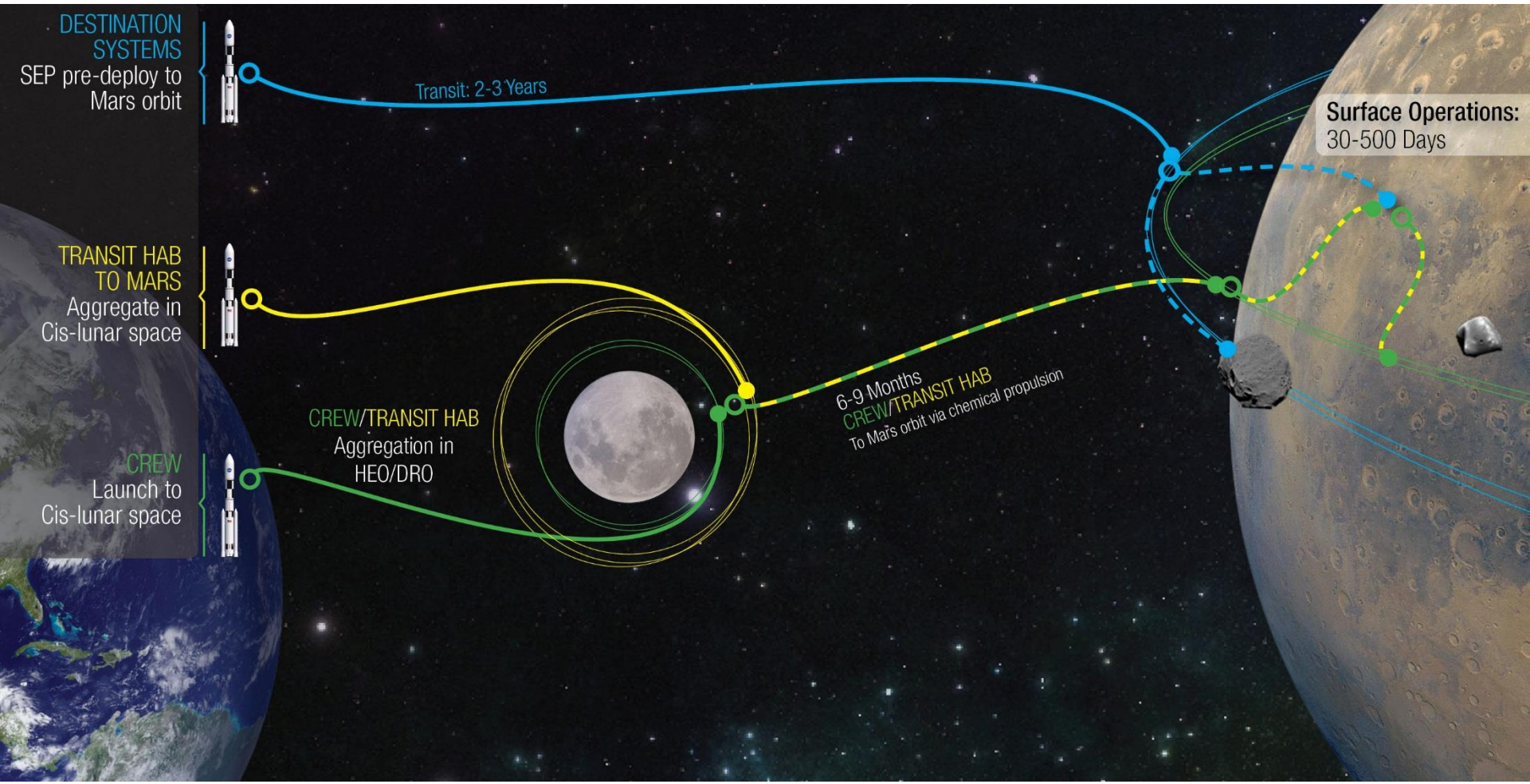


The interaction of the Earth and Moon creates bends in the energy contours that can be used to lower the energy needed to move around the Earth-Moon system and beyond, such as this example of a low energy transfer between L1 and L2 .

The Lunar Distant Retrograde Orbit leverages these equilibrium and low energy contours to enable a stable orbit with respect to the Earth and Moon, that is accessible with about the same energy as L1 or L2.

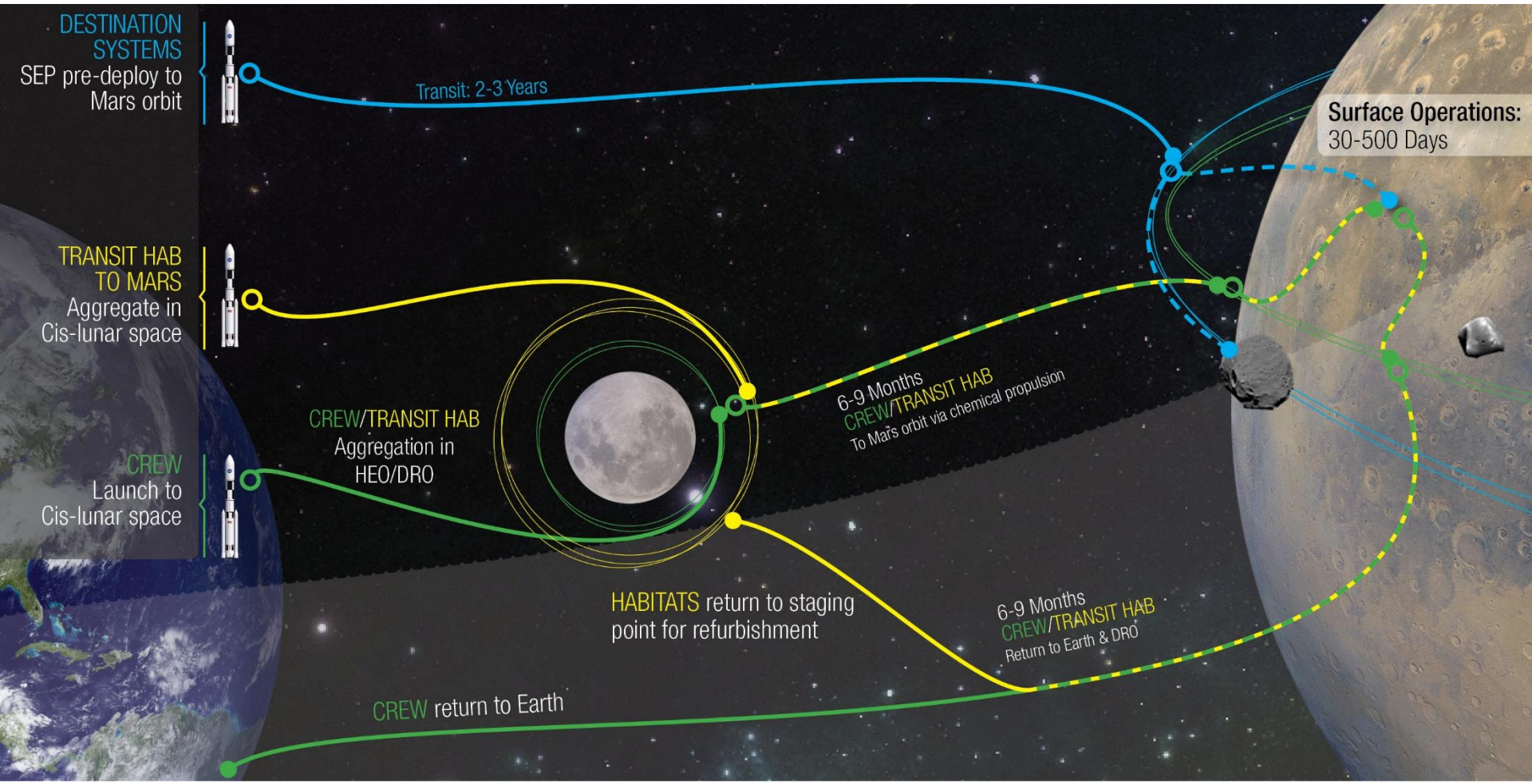
Split Mission Concept

Crew to Mars Orbit



Split Mission Concept

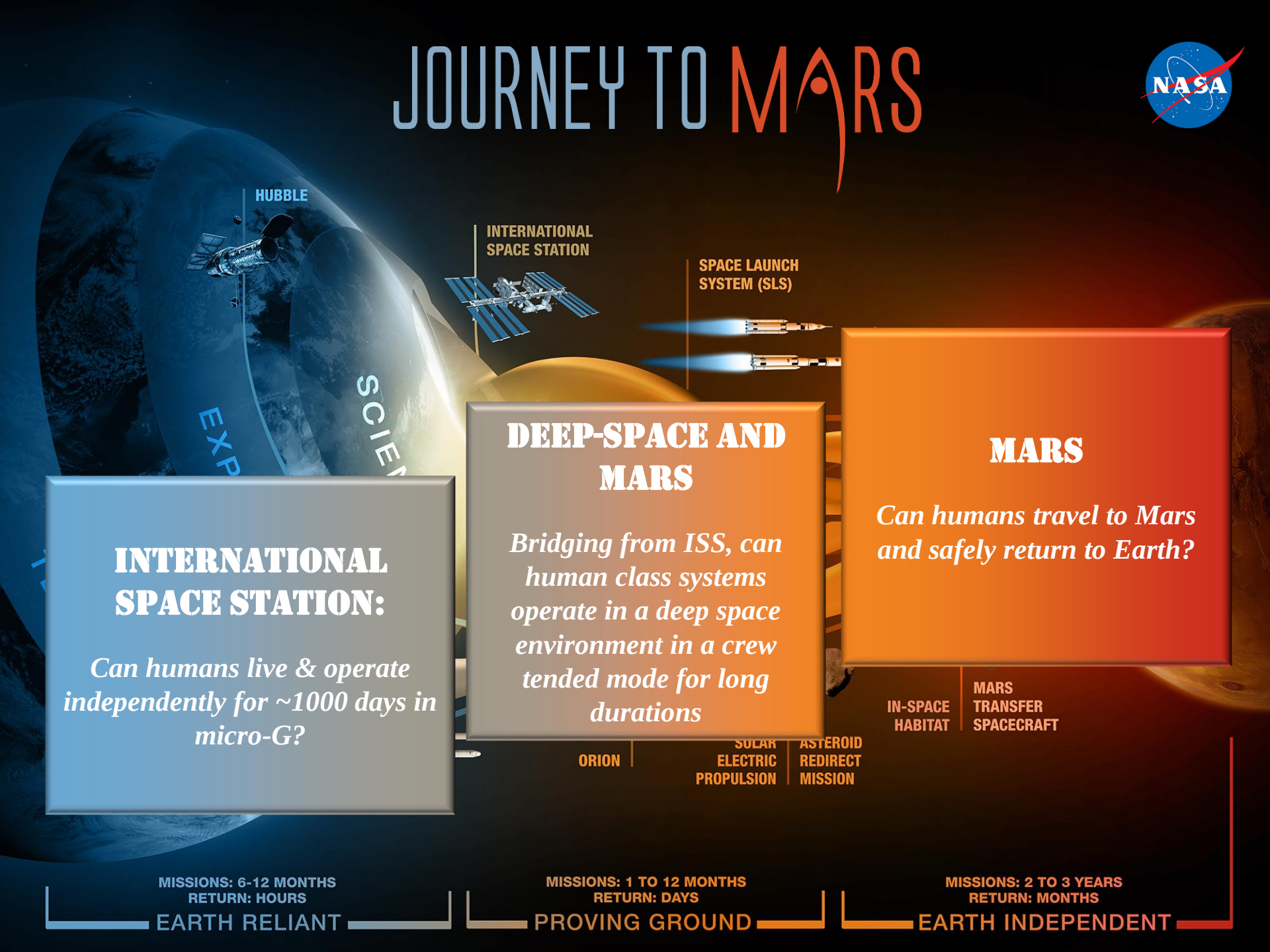
Crew Return to Earth



Pioneering Space

- Is more than the human missions to the Mars surface
- Is the ability to “go further and stay longer”
  - —With an ever decreasing need to be reliant on Earth
  - —Building an infrastructure that supports the logistics that are required for sustained living in space
- Is the gradual transition from our current permanent presence in LEO to permanent presence in deep space (which includes the surface of Mars)
- Is finding the sustainable pieces that supports the logistics and capabilities required
  - —From a technical approach
  - —But also promotes economic expansion

JOURNEY TO MARS



INTERNATIONAL SPACE STATION:

Can humans live & operate independently for ~1000 days in micro-G?

DEEP-SPACE AND MARS

Bridging from ISS, can human class systems operate in a deep space environment in a crew tended mode for long durations

MARS

Can humans travel to Mars and safely return to Earth?

MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT

MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS
PROVING GROUND

MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

So how will we go to Mars?

"Throughout human history, in any great endeavor requiring the common effort of many nations and men and women everywhere, we have learned - it is only through seriousness of purpose and persistence that we ultimately carry the day. We might liken it to riding a bicycle. You stay upright and move forward so long as you keep up the momentum."

— **Ban Ki-moon**

Secretary General, United Nations


NASA'S JOURNEY TO
MARS